

## TITLE OF THE INVENTION

### SCREW COMPRESSOR

## BACKGROUND OF THE INVENTION

### (FIELD OF THE INVENTION)

The present invention relates to a screw compressor.

### (DESCRIPTION OF THE RELATED ART)

In a general screw compressor for compressing the air by a pair of male and female screw rotors, lubricating oil is filled into a rotor chamber for lubricating and sealing between the screw rotors and between the screw rotors and the rotor chamber or for cooling the screw rotors or the like. In such a screw compressor in which the lubricating oil is used, the lubricating oil is separated from the discharged compressed air by an oil separator, and then the separated lubricating oil is filled into the rotor chamber again. The lubricating oil is also filled into bearing chambers housing bearings for supporting shafts of the screw rotors so as to lubricate the bearings. The lubricating oil overflowing from the bearing chambers is withdrawn and filled into the rotor chamber or the bearing chambers again. Since heat generated in the rotor chamber and the bearings increases a temperature of the lubricating oil, there are a number of screw compressors provided with an oil cooler for cooling the withdrawn lubricating oil.

In such a screw compressor of an oil cooling type, although the lubricating oil is separated from the discharged compressed air by the oil separator, an oil content is not easily completely removed from the compressed air. Therefore, in a food factory, a medicine factory, a precision

equipment factory or the like where the clear compressed air not including the oil content is required, it is not possible to use the screw compressor in which the screw rotors are lubricated by the oil. Consequently, a screw compressor in which water is supplied to a rotor chamber and screw rotors are lubricated, sealed and cooled by water is proposed.

However, since water has low viscosity, the screw rotors are not easily directly meshed with each other. Therefore, in a screw compressor in which metal screw rotors are lubricated by water, there is a need for providing synchronous gears meshing with each other for synchronizing the screw rotors in ends of rotor shafts. In the screw compressor, although there is also a need for lubricating the synchronous gears, bearings of the rotor shafts and a gear for transmitting rotation force of a motor to the rotor shafts, water does not easily sufficiently lubricate the above.

By adapting sliding bearings as the bearings of the screw rotors, the bearings can be lubricated even by water. However, the sliding bearings have a problem that a clearance is large so that center-adjustment accuracy is low and friction is large so that the life is short due to the friction. Therefore, rolling bearings are desirably used.

By using resin screw rotors, even in water lubrication, the screw rotors can be directly meshed with each other. However, the resin screw rotors have a larger linear expansion coefficient than metal screw rotors, and there is also a concern about absorbing water over the lapse of time and expanding. Therefore, the clearance is required to be extended and hence there is a problem of an inferior performance.

As mentioned above, in the screw compressor of a water lubricating

type, the bearings and the gears are desirably lubricated by lubricating oil. Therefore, in the screw compressor of a water lubricating type, the lubricating oil is enclosed in bearing chambers housing the bearings and the gears and oil reservoirs in which parts of the bearings and the gears are dipped are formed. However, since heat generated due to the friction between the bearings and between the gears leads to a temperature increase of the lubricating oil, there is a problem that failure in lubricating is caused or that the life of the lubricating oil is shortened. When providing incidental facility in which the lubricating oil only for lubricating the bearings and the gears is guided to the exterior of the compressor so as to perform cyclic cooling, cost is excessively increased.

### SUMMARY OF THE INVENTION

In consideration to the above problems, the present invention is to provide a screw compressor capable of cooling lubricating oil for bearings of a screw compressor, particularly a screw compressor in which screw rotors are lubricated by water.

In order to achieve the above object, a screw compressor comprises a rotor chamber, a pair of male and female screw rotors meshing with each other, the screw rotors being housed in the rotor chamber, bearings for supporting rotor shafts of the screw rotors, bearing chambers for retaining the bearings, the bearing chambers being provided with oil reservoirs for storing lubricating oil, and cooling pipes through which cooling liquid flows, the cooling pipes being formed so as to pass through the oil reservoirs.

According to the above configuration, the lubricating oil for the

bearings can be cooled down by exchanging heat with the cooling liquid through the cooling pipes within the screw compressor. Since the above configuration is simple, cost is only slightly increased, failure in lubricating is prevented by cooling down the lubricating oil, the life of the lubricating oil and the bearings is prolonged and the screw compressor can be operated at high speed.

In the screw compressor of the present invention, the cooling pipe preferably communicates with the rotor chamber so as to supply the cooling liquid to the rotor chamber.

According to the above configuration, cooling water of the screw rotors is used as the cooling liquid for cooling down the lubricating oil. Therefore, there is no need for special cooling equipment.

In the screw compressor of the present invention, at least any of the rotor shafts of the screw rotors may have a gear in the bearing chamber, and at least a part of the gear may be dipped in the oil reservoir.

According to the above configuration, not only the bearings but also the gears can be lubricated and cooled down by the lubricating oil.

In the screw compressor of the present invention, an outer shape of the oil reservoir which is just below a part of the gear at least dipped in the lubricating oil may be formed in a cylindrical shape which is slightly larger than an outer periphery of the gear.

According to the above configuration, an amount of the lubricating oil mixed by the gears and heat generation is reduced. Therefore, a temperature of the lubricating oil can be maintained low.

In the screw compressor of the present invention, the gear may be a

connection gear to which rotation force is transmitted from a drive source, or the gear may be synchronous gears provided in both the rotor shafts, the synchronous gears meshing with each other for synchronously rotating the rotor shafts.

According to the above configuration, the gears for driving and synchronizing the screw rotors can be lubricated and cooled down.

In the screw compressor of the present invention, a diameter of the cooling pipe passing through the oil reservoir in which the connection gear is dipped may be larger than a diameter of the cooling pipe passing through the oil reservoir in which the synchronous gears are dipped.

According to the above configuration, a thermal transmission area between the lubricating oil of the connection gear and the cooling liquid is larger than a thermal transmission area between the lubricating oil of the synchronous gears and the cooling liquid. And the lubricating oil of the connection gear having larger transmitted torque and larger heat generation amount than synchronous gears can be sufficiently cooled down.

In the screw compressor of the present invention, the cooling pipe passing through the oil reservoir in which the connection gear is dipped and the cooling pipe passing through the oil reservoir in which the synchronous gears are dipped may be connected to each other in parallel.

According to the above configuration, a flow rate of the cooling liquid flowing through the cooling pipe which passes through the oil reservoir in which the connection gear is dipped can be differentiated from a flow rate of the cooling liquid flowing through the cooling pipe which passes through the oil reservoir in which the synchronous gears are dipped by a pipe diameter or

the like. Therefore, a difference in a cooling effect can be freely set.

In the screw compressor of the present invention, the cooling pipes may be formed by copper pipes.

According to the above configuration, the lubricating oil can be efficiently cooled down by the copper pipes which have high thermal conductivity.

In the screw compressor of the present invention, cooling fins may be provided on the outside of casings forming the bearing chambers.

According to the above configuration, in addition to heat exchange with the cooling liquid, heat of the lubricating oil can be discharged to the outside air through the casings.

According to the present invention, by a simple configuration that the cooling pipes which pass through the oil reservoirs of the lubricating oil of the bearings of the rotor shafts are provided, the lubricating oil can be cooled down. Thereby, the failure in lubricating is prevented, the life of the lubricating oil and the bearings is prolonged and the screw compressor can be operated at high speed.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a horizontally sectional view of a screw compressor according to a first embodiment of the present invention;

Fig. 2 is a vertically sectional view of the screw compressor of Fig. 1;

Fig. 3 is a sectional view of a bearing chamber on the intake side of the screw compressor of Fig. 1;

Fig. 4 is a sectional view of a bearing chamber on the discharge side

of the screw compressor of Fig. 1;

Fig. 5 is a horizontally sectional view of a screw compressor according to a second embodiment of the present invention;

Fig. 6 is a vertically sectional view of the screw compressor of Fig. 5;

Fig. 7 is a horizontally sectional view of a screw compressor according to a third embodiment of the present invention;

Fig. 8 is a horizontally sectional view of a screw compressor according to a fourth embodiment of the present invention;

Fig. 9 is a vertically sectional view of a screw compressor according to a fifth embodiment of the present invention; and

Fig. 10 is a sectional view of a bearing chamber on the discharge side of the screw compressor of Fig. 9.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, a description will be given to embodiments of the present invention with reference to the drawings.

Figs. 1 and 2 show a screw compressor 1 according to a first embodiment of the present invention. In the screw compressor 1, a pair of male and female screw rotors (male rotor and female rotor) 4 and 5 meshing with each other are rotatably housed in a rotor chamber 3 formed in a housing 2.

The screw rotors 4 and 5 are rotated so as to intake and compress the air from an intake port 6 communicating with the rotor chamber 3 formed in the housing 2, and discharges the compressed air from a discharge port 7.

Rotor shafts 8 and 9 of the screw rotors 4 and 5 are rotatably

supported by rolling bearings 12 and 13 retained in bearing chambers 10 and 11 respectively formed on both sides of the rotor chamber 3. The rotor chamber 3 and the bearing chambers 10 and 11 are separated from each other by sealing members 14 and 15. The bearing chamber 10 on the intake side is sealed by a flange 17 of a motor 16, and the bearing chamber 11 on the discharge side is sealed by a cover 18.

In an end on the intake side of the rotor shaft 8 of the male rotor 4, a connection gear 19 is provided. The connection gear 19 meshes with a drive gear 21 provided in a motor shaft 20 protruding in the bearing chamber 10 from the flange 17 of the motor 16, and transmits rotation force of the motor 16 to the rotor shaft 8.

In ends on the discharge side of the rotor shafts 8 and 9, synchronous gears 22 and 23 meshing with each other are provided. The synchronous gears 22 and 23 synchronize rotation of the rotor shafts 8 and 9 and rotate the screw rotors 4 and 5 so as not bring the screw rotors 4 and 5 in contact with each other with maintaining a clearance.

As shown in Fig. 2, lubricating oil for respectively lubricating the bearings 12 and 13 is enclosed in the bearing chambers 10 and 11. The enclosed lubricating oil is stored on the lower side of the bearing chambers 10 and 11 and forms oil reservoirs 24 and 25 respectively. The height of liquid level of the oil reservoirs 24 and 25 is such that at least parts of the bearings 12 and 13, the connection gear 19 and the synchronous gears 22 and 23 are dipped under the liquid.

As shown in Figs. 3 and 4, the screw compressor 1 has a cooling pipe 26 formed by a copper pipe passing through from the exterior of the housing

2 to the interior thereof and further to the exterior thereof so as to pass through the oil reservoir 24 of the bearing chamber 10 on the intake side, and a cooling pipe 27 formed by a copper pipe passing through from the exterior of the cover 18 to the interior thereof and further to the exterior thereof so as to pass through the oil reservoir 25 of the bearing chamber 11 on the discharge side. The cooling pipes 26 and 27 are airtightly attached to the housing 2 and the cover 18 by bored-through joints 28 used for installing a thermocouple or the like.

As shown in Fig. 1, to the cooling pipe 26 passing through the bearing chamber 10 on the intake side, cooling water (cooling liquid) is supplied from a water cooler 29. The cooling water flowing through the inside of the cooling pipe 26 which passes through the oil reservoir 24 of the bearing chamber 10 further flows through the inside of the cooling pipe 27 which passes through the oil reservoir 25 of the bearing chamber 11 on the discharge side, and supplied to the rotor chamber 3. The cooling water supplied to the rotor chamber 3 cools down the rotor chamber 3 and the screw rotors 4 and 5, and seals between the screw rotors 4 and 5 and between the screw rotors 4 and 5 and an inner wall of the rotor chamber 3. The cooling water supplied to the rotor chamber 3 is discharged from the discharge port 7 together with the compressed air, separated from the compressed air in a gas-liquid separator 30 and returned to the water cooler 29.

In the screw compressor 1, a temperature of the lubricating oil enclosed in the bearing chambers 10 and 11 is increased by heat generation due to rolling friction between the bearings 12 and 13, friction between the

connection gear 19 and the drive gear 21 and friction between the synchronous gears 22 and 23, and heat generation due to agitation of the lubricating oil. However, the cooling water flowing inside the cooling pipes 26 and 27 exchanges heat with the lubricating oil through the cooling pipes 26 and 27 so as to take off the heat of the lubricating oil. Therefore, the temperature of the lubricating oil is prevented from being excessively increased.

As mentioned above, in the screw compressor 1, by providing the cooling pipes 26 and 27, overheat of the lubricating oil is prevented. Therefore, seizing of the bearings 12 and 13 and the gears 19, 21, 22 and 23 due to failure in lubricating can be prevented, and hence a compression ability can be enhanced by rotating the screw rotors 4 and 5 at high speed. Deterioration of the lubricating oil can be avoided by preventing the overheat of the lubricating oil, and hence maintenance cost of the screw compressor 1 can be reduced.

Next, Figs. 5 and 6 show a screw compressor 1 according to a second embodiment of the present invention. In the following description, same constituent elements as the constituent elements mentioned above will be given the same reference numerals and a description thereof will be omitted. In the screw compressor 1 according to the present embodiment, a diameter of the cooling pipe 26 passing through the oil reservoir 24 of the bearing chamber 10 which houses the connection gear 19 is larger than a diameter of the cooling pipe 27 passing through the oil reservoir 25 of the bearing chamber 11 which houses the synchronous gears 22 and 23.

The connection gear 19 transmits all the torque outputted by the

motor 16 to the rotor shaft 8 of the male rotor 4. However, the synchronous gears 22 and 23 only transmit a part of the torque of the motor 16 to the rotor shaft 9 of the female rotor 5 and synchronize both the rotor shafts 8 and 9. Therefore, a heat generation amount of the connection gear 19 and the drive gear 21 is larger than a heat generation amount of the synchronous gears 22 and 23. In the present embodiment, thermal transmission areas of the cooling pipes 26 and 27 and the oil reservoirs 24 and 25 are differentiated from each other in accordance with a heat generation amount in the bearing chambers 10 and 11 so as to cool the temperature of the oil reservoir 24 and the temperature of the oil reservoir 25 down to the substantially same temperature. It should be noted that when the diameters of the cooling pipes 26 and 27 are increased, a flow rate of the cooling water in the cooling pipes 26 and 27 is decreased. However, a rise in cooling efficiency due to an increase in the thermal transmission area is more than a drop in the cooling efficiency due to a decrease in the flow rate.

Further, Fig. 7 shows a screw compressor 1 according to a third embodiment of the present invention. In the screw compressor 1 according to the present embodiment, not only the diameter of the cooling pipe 26 passing through the bearing chamber 10 is larger than the diameter of the cooling pipe 27 passing through the bearing chamber 11 but also the cooling pipe 26 and the cooling pipe 27 are connected to each other in parallel. That is, the cooling water supplied from the water cooler 29 is diverged just in advance and supplied to the cooling pipe 26 and the cooling pipe 27 respectively. The cooling water after flowing through the cooling pipes 26 and 27 is joined together and introduced to the rotor chamber 3.

In the present embodiment, the flow rate of the cooling water in the cooling pipe 26 is not slower than the flow rate of the cooling water in the cooling pipe 27. With using an orifice or the like, a ratio between the flow rates of the cooling water of the cooling pipe 26 and the cooling pipe 27 can be freely set. Therefore, even in the case where the heat generation amount of the connection gear 19 and the drive gear 21 is considerably larger than the heat generation amount of the synchronous gears 22 and 23, a ratio between a cooling ability of the oil reservoir 24 and a cooling ability of the oil reservoir 25 can be properly set.

Further, Fig. 8 shows a screw compressor 1 according to a fourth embodiment of the present invention. In the screw compressor 1 according to the present embodiment, cooling fins 31 are protrudingly formed on the outside of the housing 2 forming the bearing chamber 10 and the cover 18 for sealing the bearing chamber 11. In the present embodiment, the heat of the lubricating oil can also be diffused to the outside air by the above cooling fins 31. Therefore, an effect of cooling down the lubricating oil enclosed in the bearing chamber 10 and the bearing chamber 11 is further enhanced.

Further, Fig. 9 shows a screw compressor 1 according to a fifth embodiment of the present invention. Further in the screw compressor 1 according to the present embodiment, as in the bearing chamber 11 shown in Fig. 10, a part of the housing 2 forming the bearing chamber 10 and a part of the cover 18 for sealing the bearing chamber 11, each part forming an outer shape of the reservoir just below the connection gear 19 or the synchronous gears 22 and 23, each part is formed in a cylindrical shape which is slightly larger than an outer periphery of the connection gear 19 or the synchronous

gears 22 and 23. That is, shapes of sections of the parts of the housing 2 and the cover 18 for forming the outer shapes of the oil reservoirs 24 and 25 which are orthogonal to the rotor shafts 8 and 9 are formed so as to be arc shapes having slightly larger diameters than outer shapes of the gears 19, 22 and 23. Thereby, amounts of the lubricating oil directly agitated by the connection gear 19 and the synchronous gears 22 and 23 are decreased so that the heat generation amount of the lubricating oil is reduced.

In the above embodiments, the copper pipes are used for the cooling pipes 26 and 27. Since the copper pipes have high thermal conductivity and can be easily installed by an inexpensive pipe joint which is commercially available, the copper pipes also contribute to reduction in manufacturing cost.

In the above, the description is given to particularly preferred embodiments in which in the screw compressor in which the screw rotors are lubricated by water, the lubricating oil in the oil reservoirs of the bearing chambers is also cooled down by the cooling water supplied to the rotor chamber. However, the present invention can also be applied to a so-called oil-free screw compressor or the like in which screw rotors meshing with each other are driven by synchronous gears and neither oil nor water is supplied to a rotor chamber.

We claim:

1. A screw compressor, comprising:  
a rotor chamber;  
a pair of male and female screw rotors meshing with each other, the screw rotors being housed in said rotor chamber;  
bearings for supporting rotor shafts of said screw rotors;  
bearing chambers for retaining said bearings, the bearing chambers being provided with oil reservoirs for storing lubricating oil; and  
cooling pipes through which cooling liquid flows, the cooling pipes being formed so as to pass through the oil reservoirs.
2. The screw compressor according to claim 1, wherein  
said cooling pipes communicate with said rotor chamber so as to supply the cooling liquid to said rotor chamber.
3. The screw compressor according to claim 1 or 2, wherein  
at least any of the rotor shafts of said screw rotors has a gear in said bearing chamber, and  
at least a part of the gear is dipped in the oil reservoir.
4. The screw compressor according to claim 3, wherein  
an outer shape of the oil reservoir which is just below a part of the gear dipped in the lubricating oil is formed in a cylindrical shape which is slightly larger than an outer periphery of the gear.
5. The screw compressor according to claim 3, wherein  
the gear is a connection gear to which rotation force is transmitted from a drive source.
6. The screw compressor according to claim 3, wherein

the gear is synchronous gears provided in both the rotor shafts, the synchronous gears meshing with each other for synchronously rotating the rotor shafts.

7. The screw compressor according to claim 3, wherein

the gear includes a connection gear to which rotation force is transmitted from a drive source and synchronous gears provided in ends on the opposite side of the connection gear in both the rotor shafts, the synchronous gears meshing with each other for synchronously rotating the rotor shafts.

8. The screw compressor according to claim 7, wherein

a diameter of said cooling pipe passing through the oil reservoir in which the connection gear is dipped is larger than a diameter of said cooling pipe passing through the oil reservoir in which the synchronous gears are dipped.

9. The screw compressor according to claim 7, wherein

said cooling pipe passing through the oil reservoir in which the connection gear is dipped and said cooling pipe passing through the oil reservoir in which the synchronous gears are dipped are connected to each other in parallel.

10. The screw compressor according to claim 1 or 2, wherein

said cooling pipes are formed by copper pipes.

11. The screw compressor according to claim 1 or 2, wherein

cooling fins are provided on the outside of casings forming said bearing chambers.